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*Published in:*  
Critical Care

*DOI:*  
[10.1186/cc1018](https://doi.org/10.1186/cc1018)

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*Document Version*  
Publisher's PDF, also known as Version of record

*Publication date:*  
2001

[Link to publication in University of Groningen/UMCG research database](#)

### *Citation for published version (APA):*

Jaarsma, A. S., Knoester, H., van Rooyen, F., & Bos, A. P. (2001). Biphasic positive airway pressure ventilation (PeV+) in children. *Critical Care*, 5(3), 174-177. <https://doi.org/10.1186/cc1018>

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## Primary research

# Biphasic positive airway pressure ventilation (PeV+) in children

Anneke S Jaarsma\*, Hennie Knoester\*, Frank van Rooyen† and Albert P Bos\*

\*University Hospital Groningen, Groningen, The Netherlands

†Dräger, Lübeck, Germany

**Correspondence:** A.S. Jaarsma, MD, Department of Pediatrics, University Hospital Groningen, PO Box 30,001, 9700 RB Groningen, The Netherlands. Tel: +31 503614215; fax: +31 503614235; e-mail: [a.s.jaarsma@bkk.azg.nl](mailto:a.s.jaarsma@bkk.azg.nl)

Received: 6 February 2000

Revisions requested: 8 August 2000

Revisions received: 11 April 2001

Accepted: 16 April 2001

Published: 2 May 2001

*Critical Care* 2001, **5**:174–177

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(Print ISSN 1364-8535; Online ISSN 1466-609X)

## Abstract

**Background:** Biphasic positive airway pressure (BIPAP) (also known as PeV+) is a mode of ventilation with cycling variations between two continuous positive airway pressure levels. In adults this mode of ventilation is effective and is being accepted with a decrease in need for sedatives because of the ability to breathe spontaneously during the entire breathing cycle. We studied the use of BIPAP in infants and children.

**Methods:** We randomized 18 patients with respiratory failure for ventilation with either BIPAP ( $n = 11$ ) or assisted spontaneous breathing (ASB) ( $n = 7$ ) on Evita 4. Lorazepam and, if necessary, morphine were used as sedatives and adjusted in accordance with the Comfort scale. We compared number of randomized mode failure, duration and complications of ventilation and number and dosages of sedatives administered.

**Results:** No differences in patient characteristics, ventilatory parameters, complications of ventilation or use of sedatives were noted. Ten out of eleven patients that we intended to ventilate with BIPAP were successfully ventilated with BIPAP. Four out of seven patients that we intended to ventilate with ASB could not be ventilated adequately with ASB but were successfully crossed over to BIPAP without the need for further sedatives.

**Conclusions:** BIPAP is an effective, safe and easy to use mode of ventilation in infants and children.

**Keywords:** assisted spontaneous breathing, biphasic positive airway pressure, children, infants, PeV+

## Introduction

Ventilatory strategies in pediatric intensive care are frequently based on strategies developed in adult or neonatal intensive care units [1]. Recently two new ventilatory techniques with almost identical names have been developed for adults: BiPAP® and BIPAP. BiPAP® is a trade name derived from 'bi-level positive airway pressure'. BiPAP® delivers, by mask, two levels of pressure in response to patient flow. It is intended to support ventilation in a non-invasive way in spontaneously but insufficiently breathing patients in the home care environment [2,3]. In contrast, BIPAP (biphasic positive airway pressure) is a mode of

ventilation developed for full ventilatory support in intensive care settings with the use of an endotracheal tube.

This paper is about BIPAP; in US literature, BIPAP is also known as PeV+. BIPAP uses cycling variations between two continuous positive airway pressure levels, allowing spontaneous breathing during every ventilatory phase [4–6]. In adults this mode of ventilation results in effective ventilation at lower inspiratory peak pressure levels, in less ventilation–perfusion mismatch, and in less dead-space ventilation [7]. Because of the ability to breathe spontaneously during every ventilatory phase, ventilation is being

**Table 1****Comfort scale [12]**

Variable	Score				
	1	2	3	4	5
Alertness	Deeply asleep	Lightly asleep	Drowsy	Fully awake and alert	Hyper alert
Calmness/agitation	Calm	Slightly anxious	Anxious	Very anxious	Panicky
Respiratory response	No coughing and no spontaneous respiration	Spontaneous respiration with little or no response to ventilation	Occasional cough or resistance to ventilator	Actively breathes against ventilator or coughs regularly	Fights ventilator, coughing or choking
Physical movement	No movement	Occasional, slight movement	Frequent, slight movements	Vigorous movement limited to extremities	Vigorous movements including torso and head
Mean arterial blood pressure	Blood pressure below baseline	Blood pressure consistently at baseline	Infrequent elevations of 15% or more (1–3 during observation period)	Frequent elevations of 15% or more above baseline (more than 3 during observation period)	Sustained elevation of 15% or more
Heart rate	Heart rate below baseline	Heart rate consistently at baseline	Infrequent elevations of 15% or more above baseline (1–3 during observation period)	Frequent elevations of 15% or more above baseline (more than 3 during observation period)	Sustained elevation of 15% or more
Muscle tone	Muscle totally relaxed, no muscle tone	Reduced muscle tone	Normal muscle tone	Increased muscle tone and flexion of fingers and toes	Extreme muscle rigidity
Facial tension	Facial muscles totally relaxed	Facial muscle tone normal, no facial muscle tension evident	Tension evident in some facial muscles	Tension evident throughout facial muscles	Facial muscles contorted and grimacing

accepted with a decreased need for sedatives [8,9]. BIPAP can be used during the entire period of artificial ventilation, including the weaning process, by prolonging the periods of low pressure level [5,10,11].

Better acceptance of ventilation, resulting in a decreased need for sedatives, would be advantageous in the ventilation of children. Increased work of breathing might be a problem in children when BIPAP is used in the weaning phase because of a prolongation of periods of low pressure levels.

No studies with BIPAP have been performed in children until now. We performed a study to determine whether BIPAP is an effective, safe and easy to use mode of ventilation in children, resulting in a decreased need for sedatives.

## Methods

### Patients and protocols

We had intended to compare BIPAP with pressure support ventilation [assisted spontaneous breathing (ASB)] with the use of Evita 4 (Dräger, Lübeck, Germany)

in 25 patients each. However, soon after the introduction of Evita 4 on the ward, physicians and nurses preferred the use of BIPAP over ASB, and inclusion of patients stopped. We therefore studied a total of 18 patients admitted to the Pediatric Intensive Care Unit of the University Hospital of Groningen. Exclusion criteria were: weight less than 3000 g, cyanotic heart disease or neuromuscular disease. Randomization was performed by the coin method and took place when paralysis, used for intubation, had been resolved. Initial ventilator settings depended on age and the reason for respiratory failure, and were adjusted according to thoracic excursions and measured tidal volume. Adjustments were made afterwards aiming at a  $p\text{CO}_2$  of 4–5 kPa and a  $p\text{O}_2$  of 8–11 kPa.

Sedatives were given in accordance with the Comfort scale (Table 1), which is a noninvasive measure for assessing distress in pediatric intensive care patients, with high inter-rater agreement and high internal consistency [12]. Good sedation is obtained when the total score is between 17 and 26. The Comfort scale was obtained by trained nurses at 2 h intervals for the first 24 h after intuba-

**Table 2**

<b>Patient characteristics</b>			
Characteristic	BIPAP ( <i>n</i> = 11)	ASB ( <i>n</i> = 7)	Significance
Age*	4 mo (6 wk to 21 months)	4 mo (4 weeks to 10 years)	<i>P</i> = 0.88
Weight*	5125 g (3300 g to 13.5 kg)	5150 g (3925 g to 27 kg)	<i>P</i> = 0.88
Numbers of each gender	5 male, 6 female	5 male, 2 female	
PRISM score*	2 (0–17)	6 (0–17)	<i>P</i> = 0.81

\*Median and range.

**Table 3**

<b>Ventilatory parameters and use of sedatives</b>			
Parameter	BIPAP ( <i>n</i> = 11)	ASB ( <i>n</i> = 7)	Significance
Randomized mode failure (no.)	1 <sup>†</sup>	4	<i>P</i> = 0.047
Duration of ventilation (days)*	9.8 ± 9.2	6.4 ± 5.8	<i>P</i> = 0.27
Atelectasis (no.)	5	3	<i>P</i> = 1.0
Accidental extubation (no.)	1	0	<i>P</i> = 1.0
<b>Sedatives</b>			
Lorazepam (all), dosage (mg/kg per day)*	0.43 ± 0.12	0.46 ± 0.16	<i>P</i> = 0.76
Morphine added (no.)	8 <sup>‡</sup>	4	<i>P</i> = 0.63
Dosage (µg/kg per h)*	9.34 ± 7.32	6.61 ± 7.10	<i>P</i> = 0.45

\*Data are shown as means ± SD. <sup>†</sup>In this patient, after transfer, ASB did not succeed either. The infant was ventilated with Babylog 8000.

<sup>‡</sup>In two patients midazolam was also added, at 100–200 µg/kg per h.

tion, and afterwards at 6 h intervals. Lorazepam (0.4 mg/kg in four divided doses) was used as sedative. To keep the Comfort scale score between 17 and 26, the lorazepam dose was adjusted as needed to a maximum of 0.6 mg/kg in six divided doses. If more sedatives were needed, morphine was added at a loading dose of 100 µg/kg and a maintenance dose of 10–20 µg/kg per hour. Randomized mode failure was recorded if, despite optimal ventilatory settings and the optimal use of sedatives, the patient could not be ventilated adequately. The patient was then transferred to the other study ventilatory mode; if neither succeeded, the study was stopped.

The recorded patient characteristics were age, weight, gender, diagnosis and paediatric risk of mortality (PRISM) score. The recorded ventilatory parameters were ventilatory mode, duration of ventilation, and complications of ventilation (atelectasis or accidental extubation). Registered parameters for adequacy of sedation were the Comfort scale and the number and dosage of sedatives.

The following endpoints of the study were considered: number of patients transferred to the alternative ventilatory mode because of inadequate ventilation or high Comfort

scale despite maximal sedative use according to study protocol, complications of ventilation, and number and dosage of sedatives administered.

### Statistical analysis

Continuous and ordinal variables were checked for normal distribution with one sample Kolmogorov–Smirnov test. Age and weight were not normally distributed and were analysed for statistical significant differences with the two-sample Kolmogorov–Smirnov test for small numbers. PRISM score, duration of ventilation, lorazepam dosage and morphine dosage were normally distributed and were analysed for statistically significant differences with the independent-samples *t*-test. Fisher's exact test was used to analyse whether statistically significant numbers of patients experienced randomized mode failure or needed the addition of morphine as a sedative.

### Results

Eighteen patients were included. Reasons for respiratory failure were diverse. In the BIPAP group, five patients were ventilated postoperatively, four patients were ventilated because of infection, one patient was ventilated because of pulmonary hypertension accompanying

cardiac disease, and one patient was ventilated because of obstruction of the upper airway. In the ASB group, two patients were ventilated postoperatively, three patients were ventilated because of infection, one patient was ventilated because of pulmonary hypertension accompanying cardiac disease, and one patient was ventilated because of obstruction of the upper airway. Patient characteristics are described in Table 2; ventilatory parameters and the use of sedatives are shown in Table 3.

No differences in patient characteristics, duration of ventilation, complications of ventilation or need for sedatives were noted.

After randomization, we intended to treat eleven patients with BIPAP, which succeeded in ten patients. The one patient that could not be ventilated with BIPAP was transferred to ASB, which did not succeed either. Afterwards the infant was successfully ventilated with Babylog 8000 (Dräger). Eight of the eleven patients needed the addition of morphine for adequate sedation.

We had intended to treat seven patients with ASB, which succeeded in three patients. The four patients that could not be ventilated with ASB were transferred to BIPAP, which succeeded in all of them. These four patients needed the addition of morphine for adequate sedation during ASB, but during BIPAP no sedatives were added.

## Discussion

BIPAP is a new mode of artificial ventilation that has been used successfully in adult patients. In adults this ventilatory mode results in a shorter duration of ventilation, a decreased need for sedatives and fewer complications in comparison with pressure controlled or pressure supported ventilation [4]. We demonstrated in the present study that BIPAP can be used safely and effectively in infants and children. We found no differences in the duration of ventilation, in the incidence of complications or in the use of sedatives in comparison with ASB. However, ventilation with ASB resulted in a significantly greater number of randomized mode failures than ventilation with BIPAP, and transfer to BIPAP resulted in successful ventilation without the need for added sedatives in all patients. We therefore believe that BIPAP might be advantageous over ASB.

However, from this study we cannot conclude that BIPAP is a better mode of ventilation for infants and children with a decreased need of sedatives than other modes of ventilation: the number of patients included was too small. We had planned to include more patients, but soon after introduction of Evita 4 on the ward, physicians and nurses preferred to use BIPAP over ASB and the patients' inclusion in the study stopped. The reasons for this preference of people on the ward for BIPAP could be one or more of the

following: a preference for the newest mode of ventilation, the increased rate of randomized mode failure in the ASB group, or the possibility of using BIPAP during the entire period of artificial ventilation without the necessity to switch between ventilatory modes when patients are paralysed or when weaning is initiated. To exclude those possible biases one would have to perform a blinded study.

We conclude that BIPAP is an effective, safe and easy to use mode of ventilation in infants and children. Its use for ventilation of infants and children during the entire period of artificial ventilation makes this mode of ventilation suitable for use in training hospitals.

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